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## Risk Analyzing on Target Type of Arson Attack

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### Abstract

An arson attack brought great social reflection in Xiamen, June 2013. In this arson, 47 people died and 34 injured on a bus. Arson is a unique category of intentional attack that results in grave consequence once occurs. This paper establishes an arson assessment model based on the particular characteristic of arson, using the risk analysis methods. 8803 arson attacks from 2000 to 2011 in Global Terrorism Database are studied. Threat, vulnerability, consequence and risk aiming at different target types are compared, so as to provide technical support against arson for defensive arrangement and macro emergency decision.

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**Keywords:** arson, intentional attack, public safety, global terrorism database, risk analysis.

### Nomenclature

$R_j$	arson risk of type $j$ target (million dollar)
$T_j$	arson threat of type $j$ target
$V_j$	vulnerability of type $j$ target to arson events
$C_j$	average arson consequence of type $j$ target (million dollar)
$N$	attack number of a category in database
$A_j$	number of attacker's arson attempts to type $j$ target
$S_j$	number of attacker's successful arson attacks to type $j$ target
<i>Greek symbols</i>	
$\omega$	subjective weight of value loss
<i>Subscripts</i>	
$j$	target type code

### 1. Introduction

Arson is the crime of intentionally and maliciously setting fire to buildings, wildland areas, vehicles or other property with the intent to cause damage. It may be distinguished from other causes such as spontaneous combustion and natural wildfires. The definition shows that arson is an attack carried out by person with intention, so it is a kind of intentional attack. Three typical cases are as follow [1].

Case1: Daegu, Korea, Feb.18 2003. A 56 years old man surnamed Kim, who was suffering severe depression, used a lighter ignite a plastic pot filled with combustibles, on the train passing through the subway station at Central Road. This train and another one approaching from the opposite direction were powered off and 12 compartments were surrounded

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with fire and smoke. The arson caused 198 people die and 146 injure. Kim confessed after arrested that he attacked in purpose of cynical mentality. "Compared to dying alone, it's better to let others die with me." As experts and media said, potentially dangerous facilities, imperfect legal system, formalistic safety education and weak safety consciousness of subway operating company were also the factors causing this event. Such sorrowful events also included the subway arson of Hong Kong happened in Feb 1<sup>st</sup>, in 2004 [2].

Case2: Xiamen, China, Jun.7 2013. A 61 years old man surnamed Chen set a fire on a bus numbered D-Y7396 on BRT line 1B from Jinshan station to Caitang station. The arson led 47 people die and 30 ones injure, including 8 college entrance exam candidates. Attacker Chen was burned to death in the arson too. The posthumous papers of Chen explained that he was pessimistic and world weary. Chen felt life unsatisfactory and made the arson out of spite. Bus facilities problem, BRT security measures and weak safety awareness of passengers are also factors in this arson [3].

Case3: Xinjiang, China, Apr.23 2013. In Selibuya, Bachu, Kashgar of Xinjiang, three community staff interviewed residents. They found several suspicious people and controlled knives at one's home. Then, the staff reported to their superiors, but were hijacked by thugs hidden in the house. Policemen and community cadres came to the scene separately, and were attacked and killed by thugs inside and outside the house. After that, thugs burned the house, all police and community cadres were killed. This violent and terrorist event caused 15 deaths including 10 Uighurs, 3 Hans and 2 Mongols, 2 Uighurs injured [4].

According to the cases above, arson have characteristic of human-induced hazards, sudden occurrence, serious damage to society, and the needs of emergency response measures. At the same time, the death in arson are deeply painful and despairing before they are dying. It's difficult to cure injured people suffered arson because of severe harm to both body and spirit. The easiness to obtain flammable liquid and lighter makes defensive against arson more difficult. Therefore, scientific and effective measures specific to different targets are in urgent need, as well as manpower and material resources against arson.

### 1.1. The variety and trend of intentional attack number

Recent decades, intentional attack highly occurred. Gary LaFree [5] et al computerize global intentional attack data from 1970s originally collected by the Pinkerton Global Intelligence Service and accumulate Global Terrorism Database. Attack properties, such as date, location, attacker, target type, attack type, weapon type, casualty and economic loss, are coded for intentional research. By the end of Sep.2013, total number of attacks reached 104,000. Fig.1 shows intentional attack information from 1970 to 2011. The figure describes that intentional attack number was in uptrend since 1970s and deceased to a controllable level since 1990s. After 2004, intentional attacks happened more frequently. The uptrend now mitigated a bit though the defense of intentional attack still faces big challenge. Data collection technology is improving since 21<sup>st</sup> century, and it is more important to analyze dynamic features of attacks in the new times. Therefore, 34886 attacks data from 2000 to 2011 are analyzed in this article.

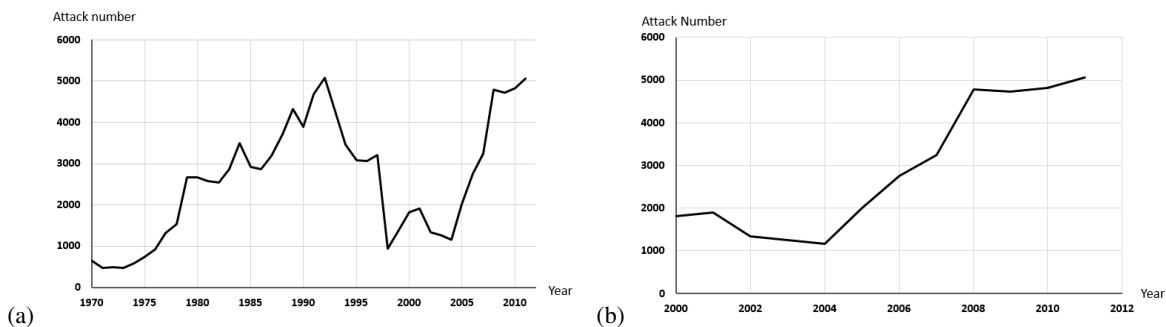


Fig. 1. Global intentional attack number in Global Terrorism Database (a) 1970-2011 and (b) 2000-2011

### 1.2. The variety and trend of arson number

"Arson" is an expression focused on attack type instead of consequence. On one hand, conflagration causes by non-human factors don't belong to the research of arson, such as forest fire. On the other hand, arson focuses on attacker's attempting to cause casualty and economic loss through combustion. The reason that explosion don't belong to arson is that the damage is from detonation wave rather than the highly occurred fires followed. There is no definition about which case

is arson in Global Terrorism Database. In this article, the data of weapon type named incendiary are used for research, including Arson/Fire, Flame Thrower and Gasoline or Alcohol [6]. Weapon type in Global Terrorism Database has 11 categories, including Incendiary, Biological, Chemical, Explosives, Fake weapons, Firearms, Melee, Sabotage Equipment, Vehicle, Unknown and Other. Fig.2 describes the change of arson from 1970 to 2011. The number of arson is significantly increasing recent years. The occurrence probability keeps at about 10% since 1980s. Table.1 and table.2 contain the top five weapon types which have largest number from 2000 to 2011 and one year count in 2011, and “Other” includes other types except first five ones. Arson threat ranks the third, next to explosion and firearms. Statistical results of different weapon types in Global Terrorism Database are shown in Fig.3.

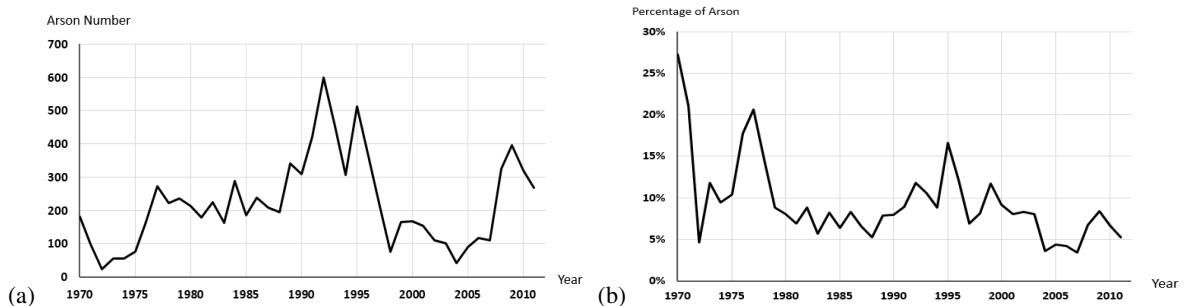


Fig. 2. Variety of arson number (a) and percentage (b) in Global Terrorism Database from 1970 to 2011

Table 1. Weapon types with more occurrence probability from 2000 to 2011

Weapon type	Incident number	Percentage
Explosives/Bombs/Dynamite	19156	54.91%
Firearms	10892	31.22%
Unknown	2066	5.92%
<b>Incendiary</b>	<b>1799</b>	<b>5.16%</b>
Melee	743	2.13%
Other	231	0.66%
Total	34887	

Table 2. Weapon types with more occurrence probability in 2011

Weapon type	Incident number	Percentage
Explosives/Bombs/Dynamite	2743	53.54%
Firearms	1626	31.74%
Unknown	336	6.56%
<b>Incendiary</b>	<b>268</b>	<b>5.23%</b>
Melee	123	2.40%
Other	27	0.53%
Total	5123	

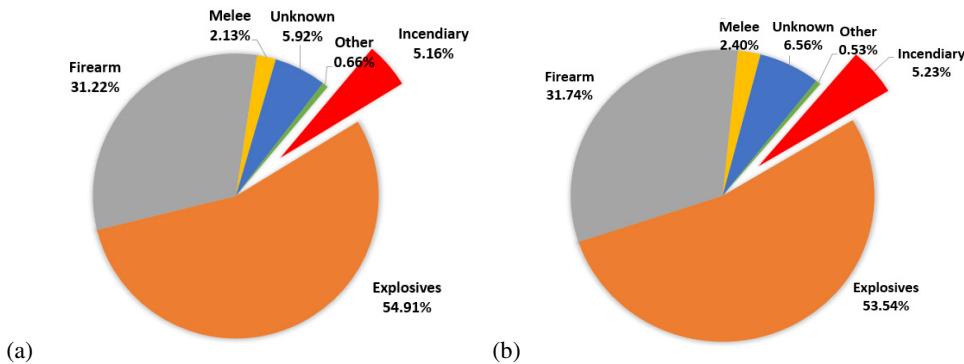


Fig. 3. Statistical results of different weapon types in Global Terrorism Database (a) 2000-2011 and (b) 2011

### 1.3. Researches at home and abroad

Internal arson studies concentrate on attack's arson motivation, arson simulation, attacker detection and firefighting management. Jin Xiufen(1992) [7] summarized and divided attack's arson motivation into 6 types such as vengeance, occultation, economics, politics, spirit and sensation seeking. Mei Xiujuan(2011) [8] considered fire scene features on subway under intentional attack, including distribution rule of heat release rate, smoke concentration, temperature, smoke density. Yang Chunying et al (2011) [9] made numerical simulation of flow field characteristics after 0.6MW arson heat suddenly released in a bus, providing distribution rule of instant velocity and temperature field. Zhi Youran et al(2009) [10] brought Bayes Network into fire investigation field. They analyzed the interaction among reason event, result event and each of the factors in case of arson with combustion improver. Yang Zhijie et al(2002) [11] analyzed problems and management countermeasures of domestic subway fire safety.

The arson study in Fire engineering, psychology, psychiatry and criminology is more completed abroad. Shen T S et al(2008) [12] used computation fluid dynamic software to provide evidences for fire investigation and to explain fire development and demonstrate smoke movement through describing the configuration of fuel, effects of ventilation and design of the building. Bradford J M et al [13] (1982) proved that arson is most frequently committed by males who suffered from personality disorder, mental retardation or depressive neurosis. Jackson H F et al [14] (1987) built the model which incorporates adaptations of the displaced aggression and arousal hypotheses of arson. They also examined possible developmental aspects of pathological arson from normal childhood fire play, as well as suggested that a transition from fire setting in the company of others to incendiarism alone constitutes a major factor in the pathological process. Fritzon K et al (2001) [15] considered two forms of destructive behavior, arson and barricade-hostage terrorist incidents, to provide support for the appropriateness of the action system framework as a way of viewing productively criminal and deviant behavior. Kocsis R N et al(2004) [16] examined the accuracy of professional profilers with others, in constructing a profile of a serial arsonist in response to case information presented, and the result is the professional profilers produced the profiles more accurate than senior detectives and fire investigators methods. Prestemon J P et al(2005) [17] used six Poisson autoregressive models of order p[PAR(p)] to estimate daily wild land arson ignition counts for five locations in Florida (1994-2001), the result reveal highly significant arson ignition autocorrelation.

According to the researches above, the uncertainty of complicated factors involved, such as analysis on psychology and characteristic of arsonists, fire scene simulation and criminal detection means, makes it difficult to study on arson. While the distribution of arson defense in different target types is lacking, which concludes arson prevention and reduction of consequential loss. Arson prevention is divided into two aspects, control of arsonist and arson process. Researches on arsonist characteristic help to recognize potential arsonists, on the other hand, control of arson utensil could decrease arson occurrence rate. However arson utensils are easily required in usual, such as gasoline, alcohol and lighters, unlike other weapons with circulating limits, making it more difficult to prevent. Refer to consequential loss, it's significant to make appropriate distribution of fire extinguishing facilities. The measure and intensity of defense are focused primarily in arson management in reality. It's common to see defensive measures like liquid inspection and firefighting facilities against subway arson, while arson defense of private property and government is vulnerable. Arson defensive intensity against different target types is the main research point of this article.

## 2. Research

### 2.1. Research method

The acceptance of risk is estimated using following formula[18], risk is a function of threat  $T$ , vulnerability  $V$  and consequence  $C$ :

$$R = T \times V \times C \quad (1)$$

Now the arson risk of different target type is analyzed. The arson threat  $T$  of the type  $j$  target can be expressed as the probability that arson incidents happened in that target type. Refer to Eq. (2), 2199 arson incident data between 2000 and 2011 are used in this study, instead of using the Delphi Method, which makes the study more statistically significant.

$$T_j = \frac{N(A_j)}{\sum_j N(A_j)} \quad (2)$$

The vulnerability of the type  $j$  target under arson attack can be expressed as the success rate of the arson attacks happened in that target type. The negative correlation between the target vulnerability and its defence capability is obvious. It could be understood that the vulnerability calculated by Global Terrorism Database would be overestimated, for the mainly source of the database is media report. Incidents with higher news value, such as successful arson attacks, are media's preference, so the unsuccessful data which are not included in Global Terrorism Database are more than the success ones. Even though, the vulnerability competition among different target types is significant in the condition of large numbers. The vulnerability of arson attack can be calculated by Eq. (3).

$$V_j = \frac{N(S_j)}{N(A_j)} \quad (3)$$

When the arson attack on the type  $j$  target success, it would lead to consequence  $C$ , which can also be called target value loss. Million dollar is used as the unit of consequence. The target value loss includes four main aspects: economic value loss, human value loss, symbolic value loss and other value loss [19]. As for arson, economic value loss means the economic loss in an arson attack, including direct consequence caused by the target function loss, and indirect consequence such as post-processing loss. Human value loss means the labor force reduce of the casualties and their relatives in an arson attack, as well as the baneful human rights influence and so on. Symbolic value loss means the loss caused by the symbolic meaning attached to the target. For example, the Reichstag Burn happened in Berlin Germany in 1933 has a higher symbolic value loss because its profound historical influence. Other value loss includes society turmoil, people's panic and so on. The consequence of arson attack can be calculated by Eq. (4).

$$C(S_j) = \omega_e e + \omega_h h + \omega_s s + \omega_o o \quad (4)$$

where  $\omega$  means the subjective weight of different value losses, related to the values of the stakeholders. Then the arson risk of different target types can be calculated by the equations above.

### 2.2. Procedure

Global Terrorism Database codes the target type into 22 categories, they are Abortion Related, Airports & Airlines, Business, Educational Institution, Food or Water Supply, Government (Diplomatic), Government (General), Journalists & Media, Maritime, Military, Non-governmental Organization, Police, Private Citizens & Property, Religious Figures/Institutions, Telecommunication, Terrorists, Tourists, Transportation, Utilities, Violent Political Party, Unknown and Others. In order to consider the newest development tendency of arson threat, the 396 attacks happened in 2009 are calculated, for the number of arson in year 2009 is the largest in the 21<sup>st</sup> century. Some types of target are rarely fired according to the database, these target types are combined into type "others". The arson threat of the different types of target between 2000 and 2011, as well as in 2009, are shown in Tab.3 and Tab.4.

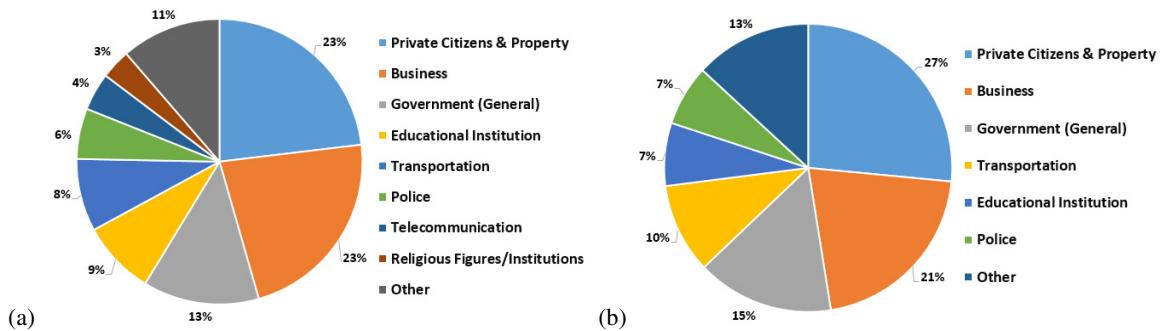


Fig. 4. The arson occurrence rate on different types of target (a) between 2000 and 2011 and (b) in 2009

Table 3. The arson threat of the different types of target between 2000 and 2011

Target type	Incident number	Threat	Target type	Incident number	Threat
Private Citizens & Property	508	23.10%	Journalists & Media	28	1.27%
Business	494	22.46%	Other	23	1.05%
Government (General)	289	13.14%	Non-governmental Organization	20	0.91%
Educational Institution	184	8.37%	Terrorists	17	0.77%
Transportation	181	8.23%	Abortion Related	13	0.59%
Police	126	5.73%	Food or Water Supply	8	0.36%
Telecommunication	94	4.27%	Violent Political Party	6	0.27%
Religious Figures/Institutions	74	3.37%	Unknown	5	0.23%
Government (Diplomatic)	47	2.14%	Airports & Airlines	4	0.18%
Military	36	1.64%	Maritime	3	0.14%
Utilities	36	1.64%	Tourists	3	0.14%
			Total	2199	

Table 4. The arson threat of the different types of target in 2009

Target type	Incident number	Threat	Target type	Incident number	Threat
Private Citizens & Property	105	26.52%	Non-governmental Organization	7	1.77%
Business	83	20.96%	Utilities	7	1.77%
Government (General)	61	15.40%	Maritime	2	0.51%
Transportation	40	10.10%	Military	2	0.51%
Educational Institution	28	7.07%	Terrorists	2	0.51%
Police	27	6.82%	Food or Water Supply	1	0.25%
Telecommunication	13	3.28%	Journalists & Media	1	0.25%
Religious Figures/Institutions	9	2.27%	Other	1	0.25%
Government (Diplomatic)	7	1.77%	Total	396	

Considering that there might be great error just using insufficient data, risk is calculated from the top 8 types in threat. Number of this kind of data is 1950, 88.68% of total events from 2000 to 2011.

The vulnerability is calculated through the information of whether a single attack is successful or not, as the results shown in Table 5 and Fig. 5.

Table 5. The arson vulnerability of the different types of target between 2000 and 2011

Target type	Attack attempt number	Successful attack number	Vulnerability
Private Citizens & Property	508	501	98.62%
Business	494	479	96.96%
Government (General)	289	280	96.89%
Educational Institution	184	181	98.37%
Transportation	181	176	97.24%
Police	126	123	97.62%
Telecommunication	94	92	97.87%
Religious Figures/Institutions	74	71	95.95%
Total	1950	1903	

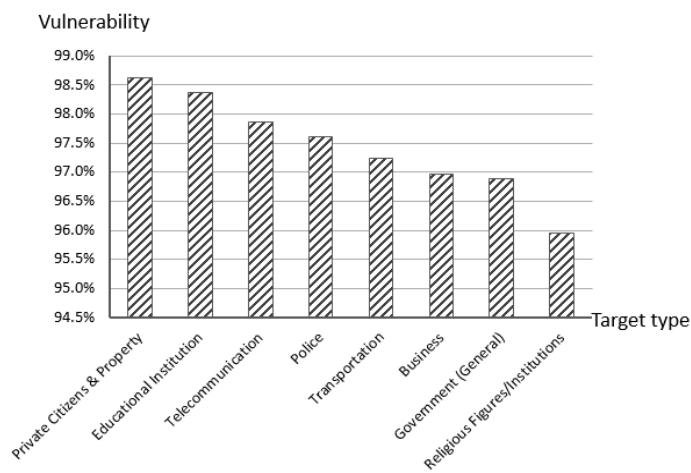


Fig. 5. The arson vulnerability of the different types of target

Global Terrorism Database mainly codes the economic value loss and human value loss. Viscusi used Value of Statistical Life to calculate the equilibrium of human value and economic value, and announced that the statistical economic value of an American worker is 7 million dollar [20]. Considering the average level of the life value in the world, it is assumed that subjective value loss weight of the dead is 1 million dollar in the following analysis, while the injured 0.01 million dollar. Subjective weight of economic value loss is 1 in the process of calculation. If there isn't any information about economic value loss of the attack, the average loss of data in the same range would be used. Consequence of different target types is shown in Table.6 and Fig.6.

Table 6. The arson attack consequence of the different types of target between 2000 and 2011

Target type	Consequence (million dollar)	Target type	Consequence (million dollar)
Religious Figures/Institutions	42.89	Transportation	2.66
Private Citizens & Property	29.11	Educational Institution	2.59
Government (General)	13.55	Business	1.74
Police	2.68	Telecommunication	1.53
		Average	12.09

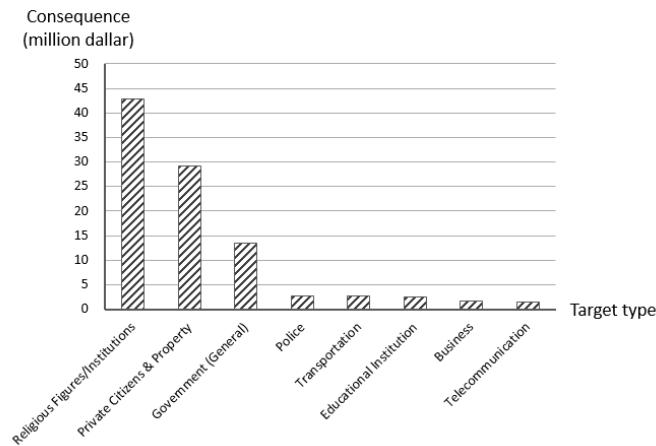


Fig. 6. The arson attack consequence of the different types of target

The arson risk of the different types of target is calculated through Eq. (1), the result is as followed:

Table 7. The arson risk of the different types of target between 2000 and 2011

Target type	Risk (million dollar)	Target type	Risk (million dollar)
Religious Figures/Institutions	42.89	Transportation	2.66
Private Citizens & Property	29.11	Educational Institution	2.59
Government (General)	13.55	Business	1.74
Police	2.68	Telecommunication	1.53
		Average	12.09

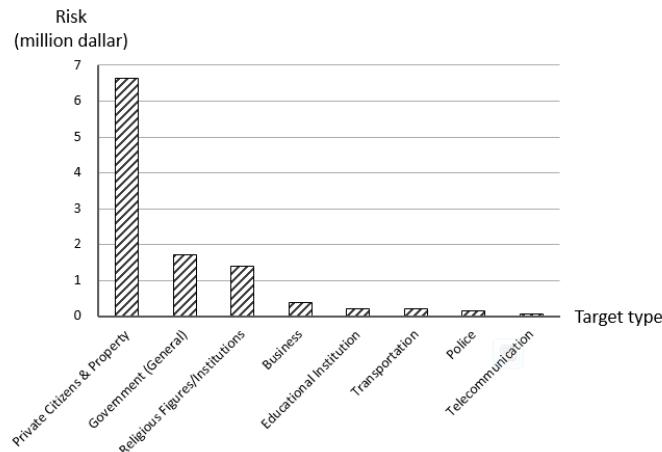


Fig. 7. The arson risk of the different types of target

### 2.3. Result

Considering the calculations above. Target types Private Citizens & Property, Business, Government (General), Educational Institution, Transportation and Police have the highest threat. Half arson happen in Private Citizens & Property and Business targets, and threat of Transportation is increasing recent years.

Target type of Private Citizens & Property has the highest vulnerability and Educational Institution comes the second. The vulnerability of Religious Figures/Institutions is the lowest.

In aspect of Consequence, target types of Religious Figures/Institutions, Private Citizens & Property and Government (General) are much more significant than others, and difference between other types is very small.

Final calculation of risk indicates that, Private Citizens & Property, Government (General) and Religious Figures/Institutions are the most risky 3 target types, and arson on Private Citizens & Property is much more risky than other types.

### **3. Discussion and Conclusion**

#### *3.1. Result Discussion*

Study results indicate that target type of private citizens and property has the highest risk. Numbers of arson on private citizens and property occur in daily news reports, just like an attacker burns other's house or vehicles for vengeance. There aren't any firefighting facilities in most families and private cars, showing the weak safety awareness of property and people themselves. The more successful an arson could be, the higher risk it would cause. In order to reduce the risk, all citizens, especially children, should learn more knowledge about fire safety. For example, install fire-extinguisher and flame retardant blanket in each family and private car, keep doors and window closed when no one at home and so on.

Meanwhile, arson on government (general) are highly risky. Citizens might be so extreme to attack government when unsatisfied about government policies. For instance, a man from Zhejiang province set a fire at town government in Nov.1st 2012 because of housing dispute. Visitors are rarely checked up about combustible materials in normal governments, which increases the risk of government as an arson target.

Arson less happened aiming at Religious Figures/Institutions in China, while arson referring to religions in other nations are usually massive. Hence the risk on religions is high, though the occurrence probability is low. However in China, it can't be overlooked that many arson happen on educational institution and transportation. One example is that a 19 years old male villager who rushed into classroom in school hour and locked the door, ignited the gasoline taken with him at a kindergarten in Gongyi, Henan on May 8, 2006. The arson caused 3 infants dead and 14 injured. Events like this are heart-breaking, and it is realized that no matter university, middle school, primary school or kindergarten, the management of people access is incomplete and there are even few safety inspections of paraphernalia in education institutions. All these weakness provide opportunities for arsonists.

Arson defense on transportations is not enough either. There are strict examinations on aircraft, train and subway, whereas the defense on short distance buses is inadequate. Large passenger capacity, crowded environment and incomplete firefighting and rescue facilities on short distance bus could increase arson risk. If there is a slight leakage of oil pipeline, the moving bus will become incendiary. Just a spark could cause an explosion, and the combustion is severe and speedy, burning out a bus within just 10 minutes. In the bus arson case in Xiamen motioned above, several passengers on the bus had smelt gasoline but didn't realize the potential risk. In order to defend arson on this target, integrated supervision system of extinguishing measures, escaping management and equipment maintenance should be set up, such as examination of auto parts, emergency hammer, fire-extinguisher, flame retardant blanket and other facilities. Public awareness of fire safety should be improved as well. In the future, small-scale combustible detecting instrument could be placed nearby doors on bus to decrease arson risk.

#### *3.2. Future Work*

Pointing out the main limitation of study could help identifying future research direction. Arson factors are numerous and complex, and the study in this article could be improved further.

On one hand, there are not enough data of China from Global Terrorism Database for statistics, so the research conclusion might not fit features of Chinese arson very well. Arson risk of different targets could be calculated in the similar method if there is a more complete domestic arson event data, to provide more effective direction of arson defensive resource allocation in China.

On the other hand, defensive information of target is lacking in Global Terrorism Database. Moreover, a majority of defensive information is from abroad and could not be proved. Thus the validity of different defensive measures couldn't be acquired in study. In further research, targeted analysis on the risk of different targets with different defensive measures is needed to adopt, so as to make more effective defense decision on each target.

### 3.3. Conclusion

The numerical variation of arson is analyzed in this article. Arson risk models of different target types are set up based on risk analysis method, which helps transform macro decision problems into analysis of existing data ones. Threat, vulnerability, consequence and risk are analyzed by large amount of real data from Global Terrorism Database, providing scientific guidance for arson defensive measures and resource allocation of different target types. In future research, both the features of internal arson and the validity of different arson defensive measures will be further studied, supplying scientific evidence for arson defense and macro emergency decision-making.

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